

# Hydrologic, Water-Quality, Sediment Transport, and Bulk Atmospheric- Deposition Data, Guanella Pass Area, Colorado, October 1, 1994, through September 30, 1997

By Michael R. Stevens

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## CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATIONS

Multiply	By	To obtain
centimeter (cm)	0.3937	inch
centimeter squared (cm <sup>2</sup> )	0.1550	inch squared (in <sup>2</sup> )
cubic foot per second (ft <sup>3</sup> /s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
gallon (gal)	3.785	liter
inch	2.54	centimeter
liter (L)	0.2642	gallon (gal)
micrometer (µm)	0.00003937	inch
mile (mi)	1.609	kilometer
milliliter (mL)	0.0610	cubic inch
millimeter (mm)	0.03937	inch
square foot (ft <sup>2</sup> )	0.0929	square meter

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$^{\circ}\text{F} = (1.8 \times ^{\circ}\text{C}) + 32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$^{\circ}\text{C} = (^{\circ}\text{F} - 32) / 1.8$$

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

## ADDITIONAL ABBREVIATIONS

mg	milligrams
mg/g	milligrams per gram
µg/L	micrograms per liter
µm	micrometer
µS/cm	microsiemens per centimeter at 25 degrees Celsius
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
NTU	nephelometric turbidity units
ROE	residue on evaporation

# Hydrologic, Water-Quality, Sediment Transport, and Bulk Atmospheric-Deposition Data, Guanella Pass Area, Colorado, October 1, 1994, through September 30, 1997

By Michael R. Stevens

## Abstract

The hydrology and water quality of streams and lakes in the Guanella Pass area could be affected by the proposed reconstruction of the existing road over Guanella Pass between Georgetown and Grant, Colo. Data were collected during water years 1995 through 1997 (October 1, 1994, through September 30, 1997) that describe the preconstruction hydrology, water quality, sediment transport, and bulk atmospheric deposition in the Guanella Pass study area with most data being collected primarily during water years 1996–97. Data were collected at 17 stream sites, 7 road-runoff sites, 10 ground-water sites, 3 lake sites, 1 reservoir site, 2 snow-precipitation sites, and 4 bulk atmospheric-deposition sites. Data include onsite measurements of streamflow, specific conductance, pH, water temperature, turbidity, barometric pressure, and dissolved oxygen; concentrations of major ions, nutrients, and trace elements; organic carbon and trace organic compounds; suspended-sediment concentration and particle-size analyses; field measurement and depth profiles, and chlorophyll concentrations in lakes and reservoirs; trace element, nutrient, and trace organic (semi-volatiles, PCBs, and insecticides) analyses of lake and reservoir bottom sediment; and bulk atmospheric deposition rates of solids. Daily values for streamflow, maximum and minimum water temperature, specific conductance, and suspended sediment were computed at seven streamflow-monitoring

stations located along South Clear Creek, Leavenworth Creek, Duck Creek, Geneva Creek, and Deer Creek.

## INTRODUCTION

The Federal Highway Administration (FHWA) proposes to reconstruct and resurface the existing road over Guanella Pass between Georgetown and Grant, Colo. (fig. 1). The hydrology and water quality of streams and lakes in the area could be affected by the proposed reconstruction. In 1994, the U.S. Geological Survey (USGS) and the FHWA began a cooperative study to determine the hydrology and water quality in the Guanella Pass area, part of the environmental investigation being conducted by the FHWA.

## Purpose and Scope

This report presents hydrologic, water-quality, sediment transport, and bulk atmospheric deposition data collected in the Guanella Pass area, primarily during water years 1996 through 1997 (October 1, 1995, through September 30, 1997), and the methods used for data collection. Some data from water year 1995 (October 1, 1994, to September 30, 1995) not included in Stevens and others (1997) also are presented.

Data were collected at 17 stream sites, 7 road-runoff sites, 10 ground-water sites, 3 lake sites, 1 reservoir site, 2 snow-precipitation sites, and 4 bulk atmospheric-deposition sites (table 1). Data include onsite measurements of streamflow, specific conduc-

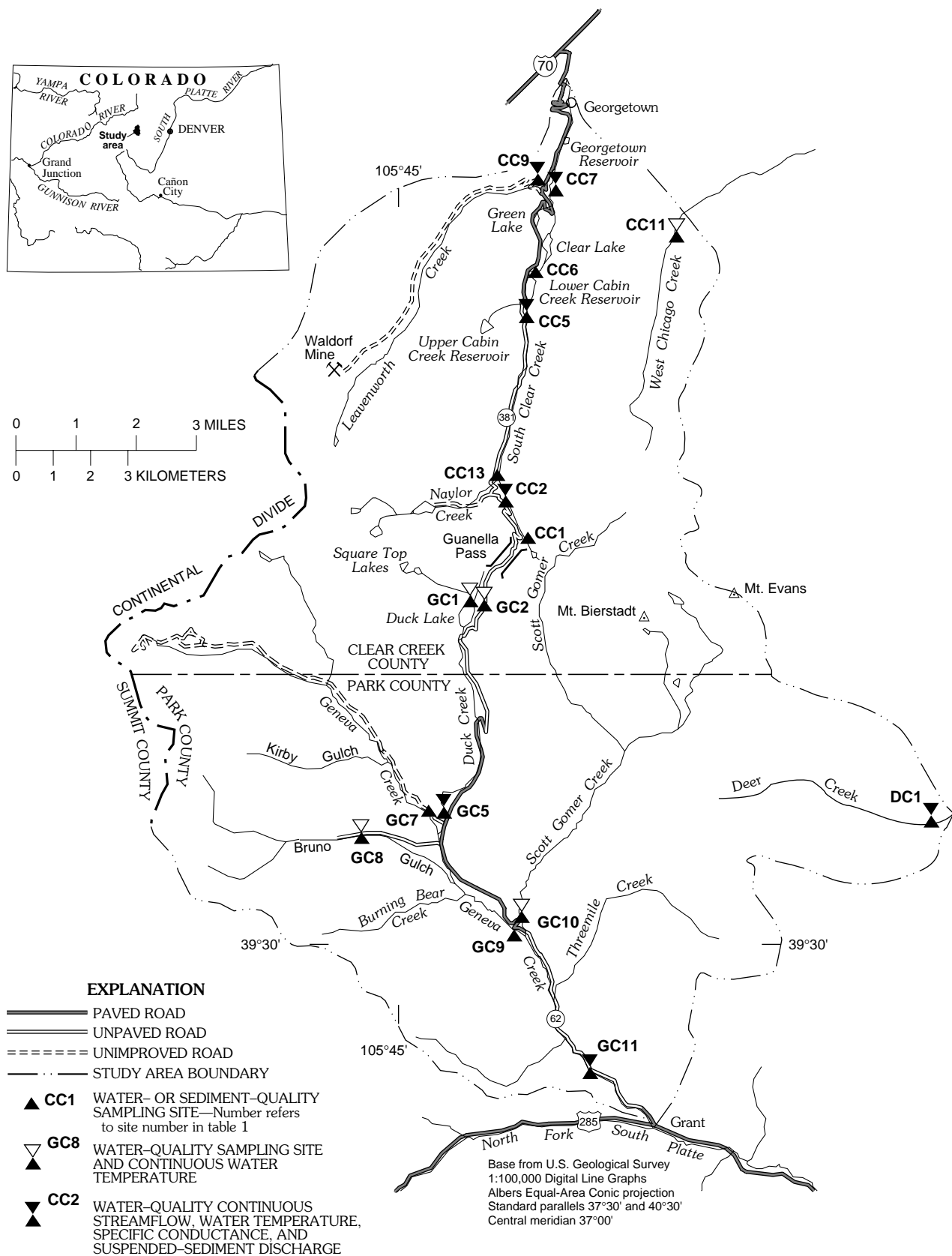


Figure 1. Location of Guanella Pass study area and stream data-collection sites.

**Table 1.** Data-collection sites

[Identification number is either an eight-digit USGS downstream order number or the latitude and longitude of the site with a two-digit sequence number at the end; see figures 1, 2, and 3 for site location; CC, Clear Creek; GC, Geneva Creek; DC, Deer Creek; CRD, Clear Creek road ditch; GRD, Geneva Creek road ditch; L, lake or reservoir; SN, snow; GW, ground water]

Site number	U.S. Geological Survey identification number	Site name
CC1	393606105422118	South Clear Creek near Guanella Pass, Colorado
CC2	393647105425317	South Clear Creek above Naylor Creek near Georgetown, Colorado
CC5	06714400	South Clear Creek above Lower Cabin Creek Reservoir near Georgetown, Colorado
CC6	393946105422203	South Clear Creek above Clear Lake, Colorado
CC7	06714600	South Clear Creek above Leavenworth Creek near Georgetown, Colorado
CC9	06714800	Leavenworth Creek at mouth near Georgetown, Colorado
CC11	394027105393900	West Chicago Creek near Idaho Springs, Colorado
CC13	393649105425301	South Clear Creek near Guanella Pass Campground near Georgetown, Colorado
GC1	393504105432312	Duck Creek above Duck Lake West Branch near Grant, Colorado
GC2	393458105431511	Duck Creek above Duck Lake East Branch near Grant, Colorado
GC5	06704500	Duck Creek near Grant, Colorado
GC7	393153105440109	Geneva Creek above Duck Creek near Grant, Colorado
GC8	393141105445808	Bruno Gulch above Geneva Park near Grant, Colorado
GC9	393018105421707	Geneva Creek above Scott Gomer Creek near Grant, Colorado
GC10	393028105421706	Scott Gomer Creek at mouth near Grant, Colorado
GC11	06705500	Geneva Creek at Grant, Colorado
DC1	393040105340400	Deer Creek near Bailey, Colorado
CRD7	393618105424200	Guanella Pass culvert #1 near Georgetown, Colorado (road runoff)
CRD8	394043105420200	Guanella Pass culvert #4 near Georgetown, Colorado (road runoff)
CRD9	394211105414300	Road ditch above Georgetown, Colorado (road runoff)
GRD4	393244105430800	Road ditch below Duck Lake near Grant, Colorado (road runoff)
GRD6	393508105430600	Guanella Pass culvert #2 near Grant, Colorado (road runoff)
GRD7	393243105430800	Campsite Road Runoff #1 near Grant, Colorado (road runoff)
GRD8	393444105444100	Road ditch near Grant, Colorado (road runoff)
G	393516105430701	Road site (bulk deposition) near Duck Lake near Grant, Colorado
L		Geneva Creek bulk deposition site L near Grant, Colorado
M		Geneva Creek bulk deposition site M near Grant, Colorado
N		Geneva Creek bulk deposition site N near Grant, Colorado
L1	393454105432900	Duck Lake near Grant, Colorado
L3	394011105425700	Clear Lake near Georgetown, Colorado
L5	393527105441900	Lower Square Top Lake near Grant, Colorado
L6	394128105415300	Georgetown Reservoir near Georgetown, Colorado
SN1	393434105432600	Duck Lake snow site near Grant, Colorado (snow chemistry)
SN2	393643105425200	Clear Creek snow site near Georgetown, Colorado (snow chemistry)
GW3	393644105430400	Guanella Pass Campground west well near Georgetown, Colorado
GW4	393638105425900	Guanella Pass Campground east well near Georgetown, Colorado
GW5	393620105423900	Guanella Pass spring #1 near Georgetown, Colorado
GW9	393610105423900	Guanella Pass spring #2 near Georgetown, Colorado
GW10	393616105423400	Guanella Pass spring #3 near Georgetown, Colorado
GW11	393342105424800	Guanella Pass spring #4 near Grant, Colorado
GW12	393335105431500	Guanella Pass spring #6 near Grant, Colorado
GW13	393627105421800	Guanella Pass spring #7 near Grant, Colorado
GW14	393036105340100	Deer Creek spring #1 near Bailey, Colorado
GW15	393145105435300	Duck Creek Picnic Ground well near Grant, Colorado



tance, pH, water temperature, turbidity, barometric pressure, and dissolved oxygen; concentrations of major ions, nutrients, and trace elements; organic carbon and trace organic compounds; suspended-sediment concentration and particle-size analyses; field measurement and depth profiles, and chlorophyll concentrations in lakes and reservoirs; trace element, nutrient, and trace organic analyses of lake and reservoir bottom sediment; and bulk atmospheric deposition rates of solids. Daily values for streamflow, maximum and minimum water temperature, specific conductance, and suspended sediment were computed for seven stream sites.

## Acknowledgments

The assistance of others in the completion of this study was invaluable. The author is grateful to Historic Georgetown, Inc., Public Service Company of Colorado, William and Julia Holmes, Clear Creek and Park Counties, and the U.S. Department of Agriculture, Forest Service, for access to property.

## DESCRIPTION OF STUDY AREA

The study area encompasses the basins of South Clear Creek and Geneva Creek and part of West Chicago Creek and Deer Creek (fig. 1), which are all tributary watersheds to the South Platte River. The West Chicago Creek and Deer Creek sites are adjacent to the South Clear Creek watershed and were added to provide additional reference (natural) sites. The tributary headwaters of Geneva, South Clear, and Leavenworth Creeks are located on the western side of the study area along the Continental Divide, and the tributary headwaters on the eastern side of the study area are located in the Mount Evans and Mount Bierstadt area. The Guanella Pass road parallels South Clear Creek from the northern terminus at Georgetown to the top of Guanella Pass at 11,669 ft. South of the pass, the road parallels Duck Creek to the confluence with Geneva Creek and then follows Geneva Creek to the southern terminus at Grant. The road has been designated a scenic byway and is called Forest Highway (FH) 80. The northern 13.1 mi, alternatively known as Clear Creek County Road 381, is in Clear Creek County. The southern 10.4 mi, alternatively known as Park County Road 62, is in Park County.

The route is maintained year round by the respective counties. Salt is applied with traction materials (sand and gravel) to parts of the road in Clear Creek County during winter. Magnesium chloride has been applied to parts of the road in Clear Creek County to control dust (Jim Cannedy, Clear Creek County, oral commun., 1997). The Guanella Pass road is 23.5 mi long; 12.1 mi are dirt or gravel and 11.4 mi are an asphalt surface (Federal Highway Administration, 1993).

The area is sparsely populated. Most residences are at Duck Lake and along Duck, Geneva, and lower South Clear Creeks. The primary land use is recreational. Livestock grazing is a limited land use in the Geneva, Scott Gomer, and Duck Creek drainages. The Mount Evans Wilderness Area encompasses much of the eastern one-half of the study area and is closed to motor vehicles. The Vidler Tunnel diverts water from upper Peru Creek across the Continental Divide into the Leavenworth Creek Basin. An aqueduct diverts water from Leavenworth Creek on a seasonal basis for maintaining water levels in Green Lake. Some of the natural lakes (Green, Clear, and Duck) have been modified for limited water storage by the construction of small dams. The Public Service Company of Colorado operates three reservoirs (Georgetown Reservoir and Upper and Lower Cabin Creek Reservoirs) in the South Clear Creek Basin for hydroelectric power generation.

Vegetation includes conifer and aspen forest at lower elevations and alpine tundra above timberline, near 11,500 ft. Annual precipitation in the study area ranges from 12 to 16 inches near Georgetown and Grant and from 40 to 50 inches on Mount Evans and the Continental Divide (Colorado Climate Center, 1984). Annual streamflows are characterized by peak flows in June resulting from snowmelt and by low flows during winter. Thunderstorms of short duration occur during summer.

Precambrian granite, gneiss, and schist compose the bedrock in the study area. Felsic intrusive rocks of Tertiary age associated with pyritic alteration underlie the headwaters of Geneva and Leavenworth Creeks (Bassett and others, 1992). Glaciers deposited drift in the valleys of Duck, Geneva, and South Clear Creeks (Tweto, 1979) and created many of the natural lakes in the area.

Ore deposits containing the minerals galena, sphalerite, pyrite, chalcopyrite, and tetrahedrite-tennantite were mined near the headwaters of Geneva

and Leavenworth Creeks in areas known as the Geneva Creek and Argentine Districts, respectively (Davis and Streufert, 1990). Naturally occurring pyritic components of the intrusive rocks and mineral deposits or mine waste materials can oxidize and produce acidic ground water and surface water in the upper basins of Geneva Creek (Bassett and others, 1992), Bruno Gulch, and Leavenworth Creek (Tweto, 1979).

## TYPES OF HYDROLOGIC AND WATER-QUALITY DATA

The hydrologic and water-quality data collected at each site (table 2) and presented in this report are the following:

1. Continuous streamflow: Daily mean discharge, in cubic feet per second.
2. Continuous specific conductance: Mean daily specific conductance, in microsiemens per centimeter at 25 degrees Celsius.
3. Continuous water temperature: Maximum and minimum daily water temperature, in degrees Celsius.
4. Daily suspended sediment: Concentration, in milligrams per liter; and sediment discharge, in tons per day (for selected stream and road-ditch sites).
5. Precipitation gage: Total daily rainfall, in inches.
6. Field properties: Instantaneous streamflow, in cubic feet per second (for stream and road-ditch sites); water temperature, in degrees Celsius; specific conductance, in microsiemens per centimeter at 25 degrees Celsius; pH, in standard units; barometric pressure, in millimeters of mercury; dissolved oxygen, in milligrams per liter; dissolved oxygen, percentage of saturation; and turbidity, in nephelometric turbidity units.
7. Major ions, dissolved concentrations: Calcium, magnesium, sodium, potassium, alkalinity (laboratory), hardness, sulfate, chloride, fluoride, silica, and dissolved-solids residue on evaporation (ROE) at 180°C, all reported in milligrams per liter.
8. Nutrient concentrations: Nitrogen, ammonia plus organic, total as N; phosphorus, total as P; nitrite dissolved as N; nitrite plus nitrate, dissolved as N; nitrogen, ammonia, dissolved as N; phosphorus, dissolved as P; and orthophosphate,

dissolved as P; all reported in milligrams per liter.

9. Trace-element concentrations, dissolved and total recoverable: Cadmium, copper, iron, lead, manganese, and zinc, all reported in micrograms per liter.
10. Organic analyses (road runoff): Total organic carbon, reported in milligrams per liter.
11. Suspended sediment (instantaneous sample): Concentration, in milligrams per liter; particle-size analysis, in percent finer than indicated size; and data were used to compute suspended-sediment discharge, in tons per day.
12. Bottom sediment chemistry concentrations (selected lakes and streams): nitrogen, ammonia plus organic, total as N; nitrogen, ammonia, total as N; phosphorus, total as P; trace-element, carbon, and trace organic compounds (semi-volatile compounds, pesticides, and PCBs); and chemical oxygen demand.
13. Lake and reservoir field-property profiles and Secchi depths: Water temperature, in degrees Celsius; specific conductance, in microsiemens per centimeter at 25 degrees Celsius; pH, in standard units; and dissolved oxygen, in milligrams per liter; Secchi depth, in inches below surface.
14. Event-related water-quality samples: Streamflow, field properties, and chemical-quality samples collected during rain events (specific properties and analytes similar to those described in list above under 1, 6, 7, 8, 9, and 10).
15. Bulk atmospheric-deposition samples: Solids weight, in milligrams, and deposition rate, in milligrams per square foot per day.

## METHODS OF DATA COLLECTION AND ANALYSIS

Details of data collection by task are described in the following sections. Data are compiled in tables 4 through 65 at the back of this report.

### Streams

Continuous and periodic water-quality data were collected from 17 stream sites in the study area (table 1, fig. 1). Continuous data, such as streamflow and water temperature, were collected or computed at

6 **Table 2.** Types of hydrologic and water-quality data collected at each site, water years 1995–97

[See table 1 and figures 1-3 for site locations; CC, Clear Creek; GC, Geneva Creek; DC, Deer Creek; CRD, Clear Creek road ditch; GRD, Geneva Creek road ditch; L, lake or reservoir; SN, snow; GW, ground water]

Site number	Continuous stream-flow	Continuous specific conductance	Continuous water temperature	Daily suspended sediment	Precipitation gage	Field properties	Major ions	Nutrients	Trace elements	Organic analysis	Suspended sediment	Sediment chemistry	Lake field-property profile and chlorophyll	Event-related water-quality samples	Bulk atmospheric deposition
CC1						X	X	X	X		X				
CC2	X	X	X	X	X	X	X	X	X		X			X	
CC5	X	X	X	X	X	X	X	X	X		X			X	
CC6												X			
CC7	X	X	X	X	X	X	X	X	X		X				
CC9	X	X	X	X	X	X	X	X	X		X			X	
CC11			X			X	X	X	X		X				
CC13						X	X	X	X		X				
GC1			X			X	X	X	X		X				
GC2			X			X	X	X	X		X				
GC5	X	X	X	X	X	X	X	X	X		X			X	
GC7						X	X	X	X		X				
GC8			X			X	X	X	X		X				
GC9												X			
GC10			X			X	X	X	X		X				
GC11	X	X	X	X	X	X	X	X	X		X			X	
DC1	X	X	X	X	X	X	X	X	X		X			X	
CRD7	X			X		X	X	X	X	X	X			X	
CRD8						X	X	X	X	X	X			X	
CRD9						X	X	X	X	X	X			X	
GRD4						X	X	X	X	X	X			X	
GRD6						X	X	X	X	X	X			X	
GRD7						X	X	X	X	X	X			X	
GRD8						X	X	X	X	X	X			X	
G															X
L															X
M															X
N															X
L1						X	X	X	X	X		X	X		
L3						X	X	X	X	X		X	X		
L5						X	X	X	X			X			
L6						X	X	X	X			X			
SN1						X	X	X	X						
SN2						X	X	X	X						
GW3						X	X	X	X						
GW4						X	X	X	X						
GW5						X	X	X	X						
GW9						X	X	X	X						
GW10						X	X	X	X						
GW11						X	X	X	X						
GW12						X	X	X	X						
GW13						X	X	X	X						
GW14						X	X	X	X						
GW15						X	X	X	X						

regular, closely spaced intervals. Periodic data, such as water-quality samples, were collected at longer scheduled intervals than streamflow data.

### Continuous Data

Seven monitoring stations (CC2, CC5, CC7, CC9, GC5, GC11, and DC1) were operated during water years 1996–97 (listed in table 1 and shown in figure 1). Stream stage, water temperature, specific conductance, turbidity (only water year 1997 at CC5), and precipitation were recorded every 15 minutes at seven sites (tables 4–24 and 37–43). These continuous data were used to compute daily mean streamflow, maximum and minimum water temperature, mean daily specific conductance, and total daily precipitation at the monitoring stations. At selected sites that did not have streamflow-monitoring stations and continuous water-temperature data, which were needed for a biological study (CC11, GC1, GC2, GC8, and GC10), maximum and minimum water-temperature data were collected using small, instream recording devices and thermistors (tables 25–29). Continuous turbidity data were of variable quality and are not presented in this report. Suspended-sediment samples were collected using an autosampler one to three times per day, and extra samples were collected during rainstorms at sites (CC2, CC5, CC7, CC9, GC5, GC11, DC1) where daily suspended-sediment discharge was computed (tables 30–36).

Continuous data from the monitoring stations (CC2, CC5, CC7, CC9, GC5, GC11, and DC1) were supported by monthly site visits during the open-water season (generally from April to October) and bimonthly visits when ice cover was present. Measurements of streamflow were made using a currentmeter by procedures given in Buchanan and Somers (1969). The calibration of water temperature and specific conductance for the water-quality monitors were checked using an ASTM thermometer, field meters, and standard solutions and were adjusted if needed according to procedures given in R.W. Boulger (U.S. Geological Survey, unpub. report, 1989). Data from these visits were used to analyze and compute the continuous data from the monitoring stations according to procedures given in Rantz and others (1982); Kennedy (1983); R.W. Boulger (U.S. Geological Survey, unpub. report, 1989).

Suspended-sediment samples were collected by the equal-width-increment (EWI) or equal-discharge-

increment (EDI) methods with a DH–48 hand sampler or DH–59 cable sampler (Guy and Norman, 1970) and by the use of an automatic pumping sampler with a fixed intake point (Edwards and Glysson, 1988) at sites CC2, CC5, CC9, CC7, GC5, GC11, and DC1, for analyses of concentration and percentage finer than 0.062 mm. Multiple daily samples collected with the manual and fixed-intake-point pumping sampler were used to compute daily sediment loads or for concurrent sediment analyses with water-quality samples. Suspended-sediment samples also were collected with manual and pumping samplers during rain events. Samplers were triggered by rain-intensity measurements at the gage. Sediment samples collected instream were used to calculate a rating coefficient for the automatic pumping sampler. Daily suspended-sediment concentrations and loads were computed using the SEDCALC computer program (Koltun and others, 1994) and by methods described in Porterfield (1972).

### Water-Quality Sampling

Water-quality samples including onsite measurements, major ions, nutrients, and trace elements were collected weekly to biweekly during snowmelt (generally from mid-May through early July) and biweekly to monthly during open-water low flow at five sites (CC2, CC5, GC5, GC11, and DC1). Additional samples at biological sampling sites (CC1, CC9, CC11, GC1, GC2, GC7, GC8, and GC10) not included in the more intensive monitoring were collected once or twice per year. Rain-event samples were collected when possible in summer by pumping sampler or manual methods. Field measurements of specific conductance, water temperature, dissolved oxygen, and barometric pressure were made at streamside (M.A. Sylvester and others, U.S. Geological Survey, unpub. methods guidelines, 1990). Turbidity and pH were measured from samples composited in a USGS churn splitter. Samples for inorganic analysis (major ions, nutrients, and trace elements) were collected by EWI methods using a DH–81 polyethylene sampler and bottle, and composited in a USGS churn splitter where separate aliquots were withdrawn for each analytical bottle required (Ward and Harr, 1990).

Rain-event samples for inorganic analysis were collected by DH–81 and fixed-intake-point pumping samplers (same as described for sediment samples) in

polyethylene bottles washed with a phosphorus-free soap and then rinsed in sequence with a 5-percent hydrochloric acid solution, deionized water, and stream water at the site.

The sample collection and processing equipment were cleaned to trace-element standards according to procedures in Horowitz and others (1994). Samples for dissolved constituents were filtered through a disposable 0.45- $\mu\text{m}$  capsule filter in an enclosed filter chamber using a peristaltic pump. Samples for trace-element analysis were preserved with trace-element-grade nitric acid. Nutrient samples were chilled to approximately 4°C. Samples collected by automatic pumping samplers for chemical analysis were chilled less than 12 hours after sample collection and then processed in the field or in the laboratory.

Samples for organic analysis were collected in a baked glass bottle by dip methods at the centroid of flow. The total organic carbon samples were not filtered. Dissolved organic carbon samples were filtered through a 0.45- $\mu\text{m}$  silver filter. Carbon samples were chilled to approximately 4°C until analyzed.

A Wolman pebble count was conducted at CC2, CC5, CC7, CC9, CC11, GC1, GC2, GC5, GC8, GC10, GC11, and DC1 to characterize the substrate particle-size distribution. Investigators measured 100 substrate particles while walking in a zig-zag pattern, from bank to bank. Three dimensions of each particle were measured and averaged (Wolman, 1954). If the particle was less than 4 mm in diameter (fine substrate), a 40-cm<sup>3</sup> sample of the substrate material was collected. All the fine-substrate samples for the reach were composited and sent to the laboratory for analysis of particle-size distribution. The results of the coarse- and fine-substrate distributions were normalized into a single particle-size distribution.

## Road Runoff

### Continuous Data

Data were collected and computed as continuous water discharge and suspended-sediment load at site CRD7, a cross-drain culvert on the Guanella Pass road (table 1, fig. 2), from May through September for water years 1996 and 1997. Water-discharge data and sediment data also were collected at sites GRD6 and GRD4 (from May through September for water years

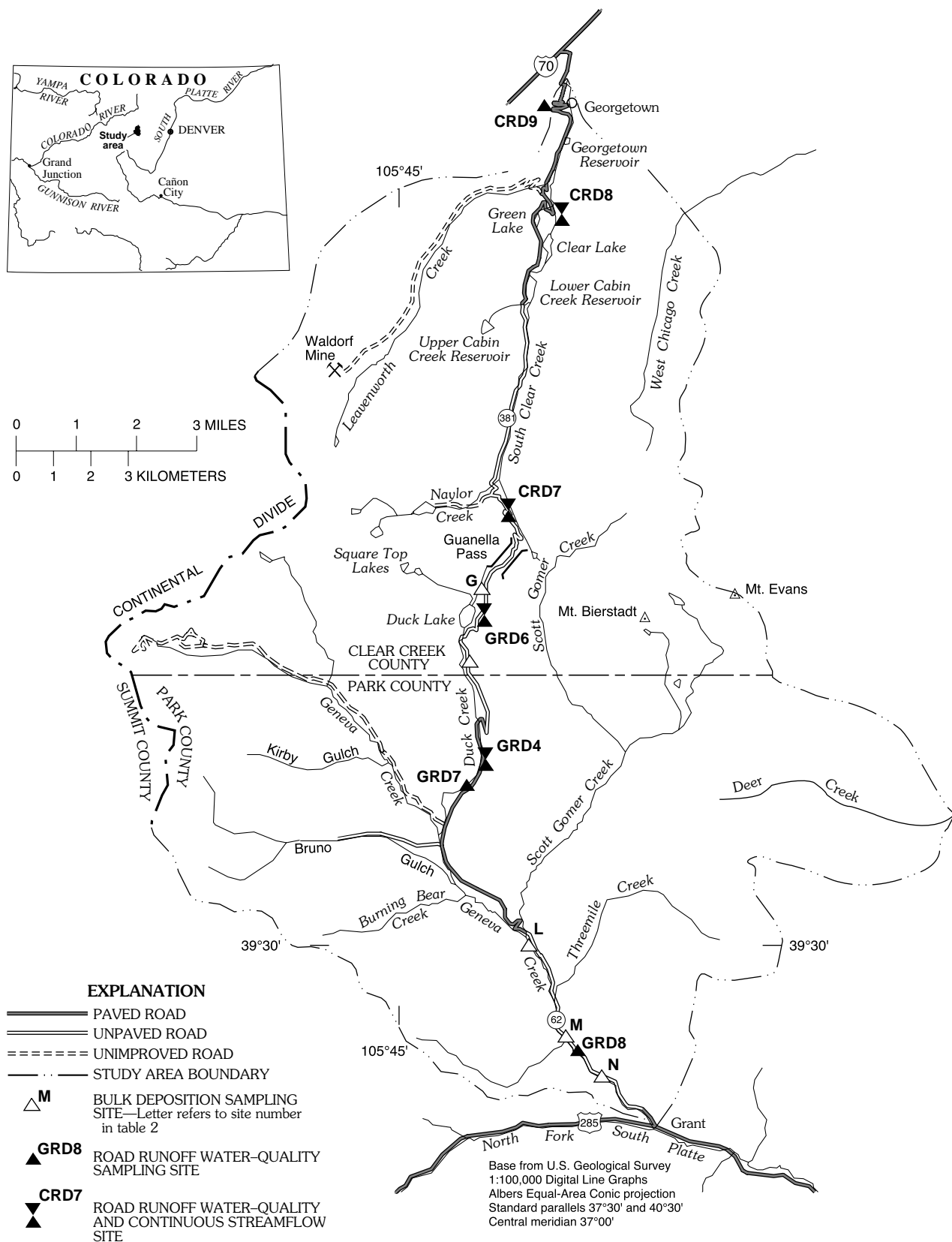
1996 and 1997) and CRD8 from July through September for water year 1997); but due to data collection problems, the data are incomplete and are presented as instantaneous water-discharge data.

Water-discharge data were collected with an electronic water-stage recorder at 5-minute intervals. A 4-inch plastic pipe was used as a well and a 3-inch float suspended vertically inside was the mechanism for driving the water-stage recorder. The control for all stages was a 120° or 22.5° v-notch weir mounted on one end of a 4-ft by 4-ft by 2-ft water-proof wood box at the end of a culvert draining the road. Standard ratings for the weirs were used directly in the absence of measurements, or a coefficient was applied according to volumetric measurement calibration data. Data from visits and the water-stage record were used to analyze and compute the continuous water-discharge data from the monitoring stations according to standard procedures (Rantz and others, 1982; Kennedy, 1983).

Daily suspended-sediment load was computed at site CRD7 by methods described in Porterfield (1972) and Koltun and others (1994). Total sediment load was not measured by sampling at the weir because sampling the shallow, sediment-laden flows in a ditch or culvert was difficult. A two-component method was used to compute sediment loads discharged from the culvert at site CRD7. Multiple daily samples were collected with an automated fixed-intake-point pumping sampler near the weir. The pumping sampler collected samples on a fixed schedule during snowmelt (May–June) and was triggered by a float-operated stage trigger during the rain-storm season (June–September). Samples collected at the weir were not adjusted for cross-section coefficient. Daily suspended-sediment concentrations and daily and annual loads were computed by methods described in Porterfield (1972) and Koltun and others (1994). The component of coarse sediment settled in the box behind the weir was periodically cleaned out and measured by volume. The bulk density was computed from samples of the coarse sediment, which allowed the load of captured sediment to be estimated. Selected bottom-material samples were submitted to the laboratory for particle-size analysis.

### Water-Quality Sampling

Road runoff in shoulder ditches and cross drains was sampled from paved sections (CRD8, CRD9,



**Figure 2.** Location of road-runoff and bulk atmospheric deposition sampling sites.

GRD4, and GRD7) and unpaved sections (CRD7, GRD6, and GRD8) of the Guanella Pass road. The sites sampled are listed in table 1 and shown in figure 2. Instantaneous water discharge (flow rate) was measured at sites CRD9, GRD7, and GRD8 using a volumetric method (Rantz and others, 1982), and water discharges at CRD7, CRD8, GRD6 and GRD4 were from continuous water-discharge records or were measured by a volumetric method. Water discharges using the volumetric method were calculated by dividing the volume of water collected in a container by the time required to collect the water. Multiple measurements were made, averaged, and converted to cubic feet per second.

Field measurements of specific conductance, water temperature, dissolved oxygen, and barometric pressure were made onsite in the ditch or drain (M.A. Sylvester and others, U.S. Geological Survey, unpub. method guideline, 1990). Turbidity and pH measurements were taken from a churn splitter in which water samples were composited or from samples collected in the automated-pump sample bottles. Samples for inorganic analysis (major ions, nutrients, trace elements) were collected by the dip method at the end of culverts, or in the centroid of flow in the ditch or at the weir, or by pumping sampler, and were processed and preserved as described in the "Streams" section of this report. Samples for total and dissolved organic carbon analyses were collected by the dip method and were processed and preserved as described in the "Streams" section of this report. Nutrient and trace-element analyses were done on selected bulk sediment samples collected behind the weirs at the continuous road-runoff monitoring sites (CRD7 and GRD6). Because flows were too shallow for EWI methods, suspended-sediment samples were collected by the dip method or with the pumping sampler and were submitted for laboratory analysis (Guy, 1969). Some daily-mean and event-mean concentration water-quality and suspended-sediment samples were prepared manually by splitting pumped samples in a Teflon cone splitter according to aliquots determined by flow weighting procedures (Martin, 1995).

## Ground-Water Sampling

Ground-water samples were collected from seven springs and three wells, which were located in

Forest Service campgrounds or picnic areas in the study area. Sampling sites are listed in table 1 and shown in figure 3. General information for selected wells is listed in table 3. Water from the wells was collected using the onsite hand pumps. The water was monitored for temperature and specific conductance during pumping, and when the water temperature and specific conductance stabilized, usually after 10 or 15 minutes of pumping, samples were collected at the outlet of the pump mechanism. Samples for major ions, nutrients, and trace elements were pumped directly into a USGS churn splitter at the hand-pump sites or dipped from springs with a polyethylene bottle and transferred to the churn.

Measurements of specific conductance and water temperature were made onsite from the outlet of the pump or the outflow from the spring. Turbidity and pH were measured from samples taken from the churn splitter. Samples for analyses of major ion, nutrient, and trace element water-quality constituents were processed and preserved as described in the "Streams" section of this report.

## Lake and Reservoir Sampling

Three lakes and one reservoir were sampled. Water-column samples, field-property profiles, and bottom-sediment samples were collected at Duck and Clear Lakes (sites L1 and L3). Bottom-sediment chemical samples were collected at Georgetown Reservoir and Lower Square Top Lake (sites L6 and L5). Sampling sites are listed in table 1 and shown in figure 3. The water-quality samples were collected in the location over the deepest part of the water body, which was determined by using a depth finder in a boat. A multiparameter water-quality instrument measured water temperature, specific conductance, pH, and dissolved oxygen for the field-property profiles. The transparency of the water was determined with a Secchi disk.

Samples for major ion, nutrient, and trace-element analyses were collected in the photic zone (estimated as two times the Secchi depth) and just above the bottom by using a Van Dorn point sampler, a horizontal PVC cylinder with end seals that are triggered by a surface messenger, lowered on a cable. Equal aliquots from the photic zone were composited from samples at 3-ft intervals. Field measurements of water temperature, specific conductance, pH, and

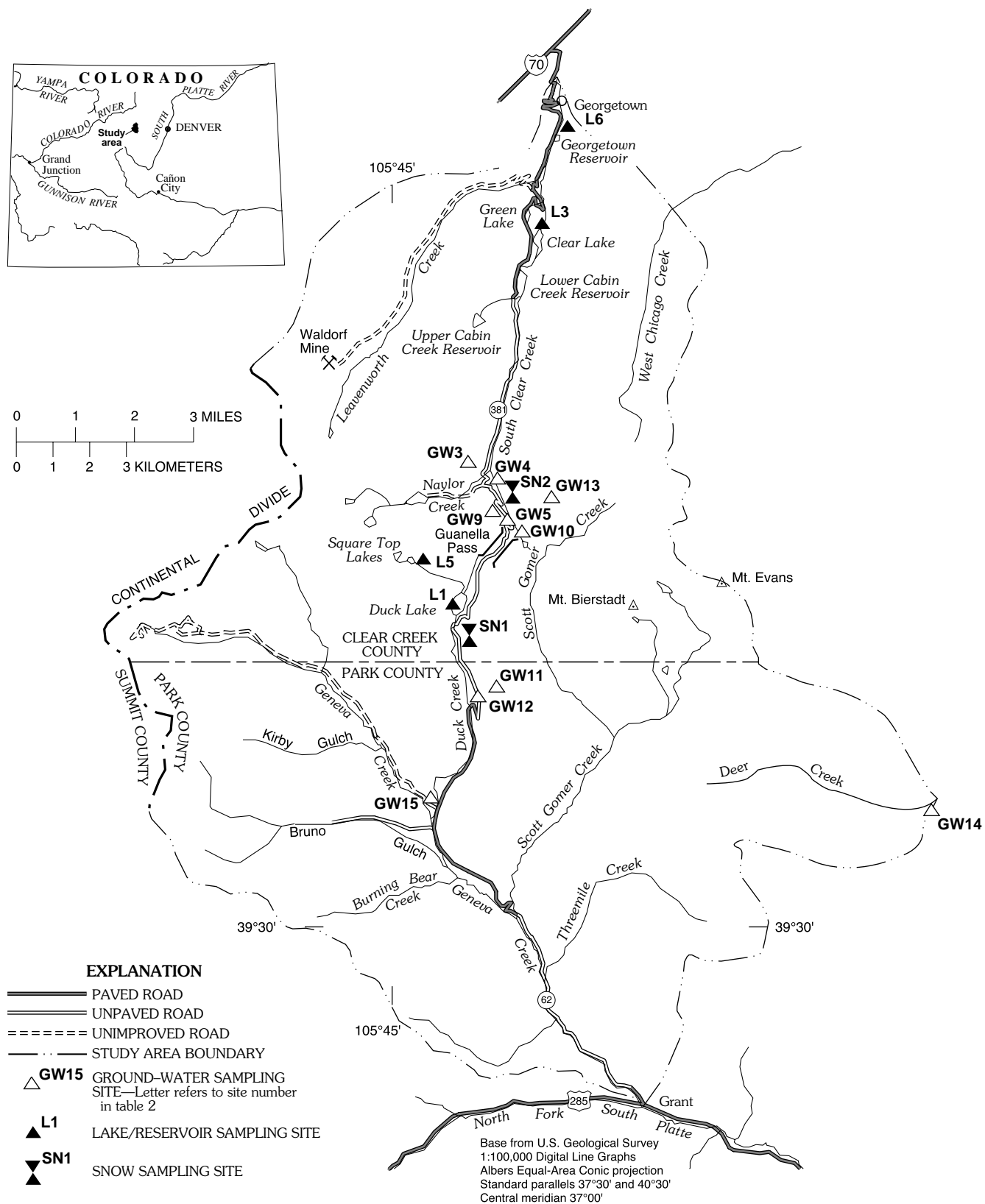


Figure 3. Location of lake/reservoir, snow, and ground-water sampling sites.



**Table 3.** Guanella Pass campground well characteristics

[Well depth, water level, and screened interval are referenced to depth below surface in feet; ---, information unavailable]

Site	Well depth	Static water level when drilled	Screened interval	Thickness of unconsolidated surficial material	Lithology of screened interval
<sup>1</sup> GW2	---	---	---	---	---
GW3	265	4	100–140	30	granitic
GW4	160	40	140–160	16	granitic
<sup>1</sup> GW7	76	47	42–76	38	granitic
<sup>1</sup> GW8	30	22	15–30	18	undifferentiated rock and surficial material
GW15	---	---	---	---	---

<sup>1</sup> Locations and water-quality samples reported in Stevens and others (1997).

dissolved oxygen were determined from measurements taken in the lake or reservoir, or from composited water samples (photic zone). Sample water for inorganic analyses was transferred to clean, acid-rinsed, deionized-water rinsed, and native-water rinsed polyethylene containers. Samples were transferred to a clean, acid-rinsed, deionized-water rinsed, and native-water rinsed USGS churn splitter and then processed and preserved as described in the "Streams" section of this report. Chlorophyll-*a* samples were collected from the photic-zone composite and processed according to methods described in Britton and Greeson (1987).

Grab samples of bottom sediment, analyzed for nutrients and trace elements, were obtained at the location of the water samples for sites L1 and L3 and at the near shore for sites L5 and L6. A polyurethane-coated-stainless-steel, center-pivot-jaw dredge sampler (petite ponar) was lowered to the bottom from a boat. At sites L5 and L6, a plastic bucket was used for sampling at a location reached by wading out from the shore. The sample was removed from the center of the dredged material, sieved (nylon mesh) using native water to less than a particle size of 0.062 mm, and placed in plastic or glass containers (depending upon analysis requested). Samples were chilled to approximately 4°C for transport to the laboratory for analysis.

## Snow Sampling

Snowpack was sampled once at sites SN1 and SN2 in late March 1997 and 1998. Sampling sites are listed in table 1 and shown in figure 3. The sites were at least 300 ft away from any roadway. Sampling locations were chosen in small, sheltered clearings that were not prone to drifting. Metallic shovels were used to dig a pit in the snow down to the ground surface with the sampling face away from direct sunlight. The final sampling face was exposed by a polyethylene scoop that was cleaned to trace-element standards with acid and deionized-water rinses. Snow was removed in a uniform vertical channel, excluding the 5 cm of snow above the soil/snowpack interface.

The snow was placed in USGS churn splitters and Teflon bags, cleaned to trace-element standards with acid and deionized-water rinses, and allowed to melt at room temperature. Immediately after the snow was melted, the meltwater was carefully combined into a single churn (when more than one churn was used for melting the sample) for filling sample bottles. Specific conductance and pH were measured using samples of the meltwater from the churn. Samples for selected major ions, nutrients, and trace element analyses were processed and preserved as described in the stream-water quality section of this report.

## Bulk Atmospheric-Deposition Sampling

Bulk atmospheric-deposition (dust) samples were collected at site G during water year 1996 and sites L, M, and N during water year 1997. In water year 1996, site G (along an unpaved section of road) was monitored by collectors placed at several distances on the west and east sides of the Guanella Pass road for 56 days. In 1997, bulk atmospheric deposition was measured along the lowermost gravel/dirt section of the Guanella Pass road at sites L, M, and N for 61 days. Sampling sites are listed in table 1 and shown in figure 2.

White polyethylene buckets (5-gal capacity) were used as collection devices and were placed at varying distances from the edge of the road. Collector distances from the road varied from site to site and are detailed in the "Hydrologic and Water-Quality Data" section (table 61 at back of report). The collectors were anchored at ground level with plastic ties to

painted reinforcing bars pounded into the ground. A clear, plexiglas, vertical baffle was placed in each collector to prevent wind from expelling collected contents. The collectors were washed and kept covered by lids until the beginning of each collection period. At the end of each collection period, the collectors were tightly covered in the field and transported to the laboratory for processing and analysis.

The collectors accumulated material deposited from the air above the collectors. This material might include atmospheric particles, side-cast or windblown particles, loose particles bouncing downslope, particles from raindrop-impact splash, throughfall from vegetation, vegetation debris, insects, and precipitation. These data include only deposited material and might not relate to visible or fugitive dust.

To measure the quantity of accumulated material, the dust collectors were washed with any accumulated precipitation and, if necessary, deionized water. The volume of wash water was measured after being drained from the collector through a 2-mm sieve to remove large debris. The wash water was put into 1-L polyethylene containers. If necessary for shipping convenience, the wash water was split with a Teflon cone splitter into smaller volumes. These samples were analyzed for sediment concentration and particle size. The bulk deposition was calculated by multiplying the sediment concentration by the total volume of wash water.

## LABORATORY ANALYSIS

All samples collected for major ion, nutrient, and trace-element analysis were analyzed at the USGS National Water Quality Laboratory in Arvada, Colo., using standard analytical techniques described in Fishman and Friedman (1989), Fishman (1993), and Fishman and others (1994). Samples collected for concentrations of organic constituents were analyzed at the same laboratory using standard analytical techniques described in Wershaw and others (1987) and Fishman (1993). Suspended-sediment and bed-material samples were analyzed at the USGS Iowa Sediment Laboratory in Iowa City, Iowa.

## QUALITY ASSURANCE

Sampling equipment and water-quality meters are checked regularly and calibrated in the field or office. Deionized water used in cleaning and sample processing is monitored for purity according to procedures in Horowitz and others (1994).

Laboratory and field cleaning procedures are rigorous and designed to prevent contamination of samples. Prior to sample collection, all sampling equipment and materials were cleaned according to standard procedures described in Horowitz and others (1994). The procedures involve a soak and wash in nonphosphorus detergent, soak and rinse in tapwater, followed by a soak and rinse in a 5-percent hydrochloric acid solution, and a final soak and rinse in deionized water.

Field blanks and replicates were processed each water year (tables 64 and 65). Field blanks are processed onsite with the equipment used for sampling using inorganic blank water. Specific types of blank water were used for inorganic and organic blank samples. The field blanks are used to assess bias from contamination during collection, processing, or laboratory analysis. The water collected was analyzed for the same constituents analyzed for during the study.

When questionable results for a particular analyte were received from the laboratory, a repeat analysis of the same sample was requested. If the second analysis was more consistent with known characteristics of the site or the particular sample, the new result was used instead of the previous result. There are several samples in which the dissolved concentration of a trace element was reported to be higher than the total recoverable concentration. These inconsistencies are within the precision of the methods used and are due, in part, to the differences between the analytical technique used for dissolved (inductively coupled plasma mass spectrometer, atomic absorption, or graphite furnace atomic absorption) and total recoverable trace elements (atomic absorption or graphite furnace atomic absorption), and the differences between particular aliquots of sample. The analytical quality-assurance practices and procedures of the National Water Quality Laboratory are described in Friedman and Erdmann (1982).

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# HYDROLOGIC AND WATER-QUALITY DATA

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## TERMS AND ABBREVIATIONS

The following terms and abbreviations are used in tables 4-65:

lat	latitude
long	longitude
sec.	section
S.	south
W.	west
T.	township
R.	range
mi	mile
mi <sup>2</sup>	square mile
ft	feet

Oct	October
Nov	November
Dec	December
Jan	January
Feb	February
Mar	March
Apr	April
Jun	June
Jul	July
Aug	August
Sep	September
MAX	the maximum daily mean discharge for a given month
MIN	the minimum daily mean discharge for a given month
AC-FT	acre-foot
YYYY.MM.DD	Date: year, month, day
HHMM	24-hour time
mm/dd/yy	numerical date format for two-digit month/two-digit day/ and the last two digits of the year
---	a symbol used in place of daily mean discharge for periods of missing record or periods prior to gaging-station activation
C	Celsius
Deg.	degree
cm	centimeters

°	degree
mm	millimeters
in.	inch
24 hr	the time of day in 24-hour format
cfs	cubic feet per second
ft <sup>3</sup> /s	cubic feet per second
μS/cm	microsiemens per centimeter at 25°C
pH units	are the negative base-10 log of the hydrogen-ion activity in moles per liter
NTU	nephelometric turbidity units
mm Hg	millimeters of mercury
mg/L	milligrams per liter
μg/L	micrograms per liter
dissolved	refers to that fraction of material in a water sample that passes through a 0.45-μm membrane filter
total	refers to total recoverable; the amount of a constituent that is in solution after a water and suspended-sediment sample has been digested by a method that results in the dissolution of only readily soluble substances
---	no data
>	greater than
<	less than
NS	no sample
gm/kg	grams per kilogram
mg/kg	milligrams per kilogram



$\mu\text{g/kg}$	micrograms per kilogram
$\mu\text{g/g}$	micrograms per gram
Mg	megagram
mg	milligram
$\mu\text{g}$	microgram
%	percent
$\mu\text{m}$	micrometer
$\text{cm}^2$	square centimeter
$\text{ft}^2$	square foot
T	ton (short), 2,000 pounds
d	day
D	dip sampling method
P	automatic pumping sampler method